

Image Processor Capable of Reducing Gradation at High Speed

This application is based on application No. 11-299437 filed in Japan, the contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an image processor, and more particularly, it relates to an image processor converting M-valued image data of a target pixel to N ($M > N$)-valued image data (N-arization) on the basis of error diffusion.

Description of the Related Art

An image processor utilizing error diffusion is known in general. General error diffusion is performed on the basis of the following equation.

Assuming that I_{xy} ($0 \leq I_{xy} \leq 1$) represents input image data of a pixel (target pixel) having coordinates (x, y) and B_{xy} (0 or 1) represents output two-valued image data (N-valued image data), two-valued error data E_{xy} is expressed as follows:

$$E_{xy} = I_{xy} - B_{xy} \quad \dots (1)$$

According to the error diffusion, the image data I_{xy} of the target pixel is corrected with an average weighted error $EAVE_{xy}$ of two-valued errors of peripheral pixels thereof, in order to reduce the two-valued error data E_{xy} on the average. The average weighted error $EAVE_{xy}$ is obtained as follows:

$$EAVE_{xy} = \sum K_{ij} \times E_{ij} \quad \dots (2)$$

In general, the weighting factor K_{ij} is increased as approaching the target pixel. As shown in Fig. 3, a filter computes the average weighted error $EAVE_{xy}$ generally with a matrix size i of five pixels along the main scanning direction of the filter and a matrix size j of two to three pixels along the subscanning direction. The weighting factor K_{ij} is increased as approaching the target pixel (denoted by "*" in Fig. 3).

Corrected image data I'_{xy} of the target pixel is expressed as follows:

$$I'_{xy} = I_{xy} + EAVE_{xy} \quad \dots (3)$$

The obtained corrected image data I'_{xy} is binarized with a prescribed threshold Th .

$$B_{xy} = 1 \text{ (when } I'_{xy} \geq Th)$$

$$B_{xy} = 0 \text{ (when } I'_{xy} < Th) \quad \dots (4)$$

The two-valued error data E_{xy} is computed from the corrected image data I'_{xy} and a reference value B'_{xy} obtained on the basis of the result of binarization (two-valued image data).

$$E_{xy} = I'_{xy} - B'_{xy} \quad \dots (5)$$

In general, the reference value B'_{xy} is:

$$B'_{xy} = HB \text{ (when } B_{xy} = 1)$$

$$B'_{xy} = LB \text{ (when } B_{xy} = 0) \quad \dots (6)$$

The reference values HB and LB are given by the upper limit (= 1) and the lower limit (= 0) of the dynamic range of the pixel respectively.

Fig. 4 is a block diagram showing the structure of a conventional image processor employing error diffusion.

Referring to Fig. 4, the image processor is formed by an error storage memory 1, an error computing part (product-sum operation part) 2 computing errors on the basis of an error weighting filter, an adder 3, a comparator 4, a subtracter 5 and a selector 6.

The error storage memory 1 stores two-valued errors necessary for computing the average weighted error $EAVE_{xy}$. The error storage memory 1 outputs the two-valued errors to the error computing part 2. The error computing part 2 performs a product-sum operation of the weighting factor K_{ij} and the errors for computing the average weighted error $EAVE_{xy}$ and outputting the same to the adder 3 (the processing of the above equation (2)).

The adder 3 adds the image data I_{xy} of the target pixel with the average weighted error $EAVE_{xy}$ of the peripheral pixels and computes the corrected image data I'_{xy} . Then, the adder 3 outputs the corrected image data I'_{xy} to the comparator 4 for binarization and the subtracter 5 for error computing (the processing of the above equation (3)).

The comparator 4 compares the corrected image data I'_{xy} with the prescribed threshold Th (e.g. "127") to obtain the two-valued output B_{xy} as a result and outputs the result of the comparison to the selector 6 for selecting the reference value (the processing of the above equation (4)).

The subtracter 5 subtracts the corrected image data I'_{xy} from the reference value B'_{xy} and outputs the obtained two-valued error data E_{xy} to the error storage memory 1 (the processing of the above equation (5)).

5 The selector 6 selects the reference value (HB or LB) for computing the two-valued error data E_{xy} from the two-valued image data B_{xy} , and outputs the selected reference value B'_{xy} to the subtracter 5.

Referring to Fig. 4, the error computing part 2 computing the average weighted error $EAVE_{xy}$ of the peripheral pixels, the adder 3 adding the average weighted error $EAVE_{xy}$ to the input image data I_{xy} and
10 computing the corrected image data I'_{xy} , the comparator 4 comparing the corrected image data I'_{xy} with the threshold Th and computing the two-valued image data B_{xy} , the selector 6 for selecting the reference value B'_{xy} from the two-valued image data B_{xy} and the subtracter 5 computing the two-valued error data E_{xy} from the corrected image data I'_{xy} and the
15 reference value B'_{xy} form a feedback loop of errors.

In order to binarize the image data I_{xy} of the target pixel, the average weighted error $EAVE_{xy}$ of the peripheral pixels must be operated inclusive of a two-valued error $E_{x-1,y}$ of a precedently binarized pixel. In other words, the processing of the above equations (2) to (6) must be entirely performed
20 in a cycle processing a single pixel. If the processing in the feedback loop is performed at a slow speed, therefore, the processing speed of the overall image processor is reduced.

SUMMARY OF THE INVENTION

25 An object of the present invention is to provide an image processor having a high processing speed.

In order to attain the aforementioned object, an image processor converting M -valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion according to an aspect of the present invention comprises a correction part correcting the M -valued image data of
30 the target pixel with an N -valued error resulting from N -arization of peripheral pixels for the target pixel and generating corrected image data, an N -arization part comparing the corrected image data with a threshold and converting the corrected image data to N -valued image data of the

target pixel and an output part outputting an N-valued error having a smaller bit number than the corrected image data by multivalued dithering on the basis of the corrected image data and the N-valued image data.

According to another aspect of the present invention, an image processor converting M-valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion comprises a correction part correcting the M-valued image data of the target pixel with an N-valued error resulting from N-arization of peripheral pixels for the target pixel and generating corrected image data, an N-arization part comparing the corrected image data with a threshold and converting the corrected image data to N-valued image data of the target pixel and an output part outputting an N-valued error having a smaller bit number than the corrected image data on the basis of the corrected image data and the N-valued image data.

According to still another aspect of the present invention, an image processing method of converting M-valued image data of a target pixel to N ($M > N$)-valued image data by error diffusion comprises steps of correcting the M-valued image data of the target pixel with an N-valued error resulting from N-arization of peripheral pixels for the target pixel and generating corrected image data, comparing the corrected image data with a threshold and converting the corrected image data to N-valued image data of the target pixel and outputting an N-valued error having a smaller bit number than the corrected image data on the basis of the corrected image data and the N-valued image data.

The foregoing and other objects, features, aspects and advantages of the present invention will become more apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing the structure of an image processor according to a first embodiment of the present invention;

Fig. 2 is a block diagram showing the structure of an image processor according to a second embodiment of the present invention;

Fig. 3 illustrates the structure of an error weighting filter; and Fig. 4 is a block diagram showing the structure of a conventional image processor.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Fig. 1 is a block diagram showing the structure of an image processor according to a first embodiment of the present invention. The difference between this image processor and the image processor shown in Fig. 4 is now described.

According to this embodiment, a multivalued dithering part 7 is provided between an adder 3 and a subtracter 5. The multivalued dithering part 7 bit-reduces corrected image data I'_{xy} by multivalued dithering, and outputs bit-reduced corrected image data I''_{xy} to the subtracter 5.

The multivalued dithering part 7 applies dithering to lower L bits of the corrected image data I'_{xy} consisting of K bits and converts the data of the lower L bits to 1-bit data. Thus, the multivalued dithering part 7 converts the corrected image data I'_{xy} consisting of K bits to the bit-reduced corrected image data I''_{xy} .

The dithering is a pseudo-gradation method (area gradation method) expressing gradation by a set of dots similarly to the error diffusion, and hence the quantity of information per dot is reduced due to the bit reduction while the quantity of information of the original image is preserved by the set of the dots.

A selector 6 outputs one of reference values HB and LB in response to a result B_{xy} of binarization. The reference values HB and LB have the same bit number as the bit-reduced corrected image data I''_{xy} .

The subtracter 5 subtracts a reference value B'_{xy} from the bit-reduced corrected image data I''_{xy} and outputs the result as two-valued error data E_{xy} . The bit number of the two-valued error data E_{xy} , requiring a bit indicating \pm , is larger than that of the bit-reduced corrected image data I''_{xy} by 1. An error storage memory 1 stores the value of the two-valued error data E_{xy} .

An error computing part 2 employs an error weighting filter and

the bit number of the corrected image data I'_{xy} by multivalued dithering and thereafter computes an N-valued error, the image processor according to the second embodiment reduces the bit number of difference data E_{xy} between corrected image data I'_{xy} and a reference value based on N-valued image data by a multivalued dithering part 7. The bit number of error data can be reduced also by reducing the bit number of the two-valued error E_{xy} , whereby a load on a product-sum operation can be reduced and the speed of a feedback loop for errors can be increased.

While each of the above embodiments has been described with reference to the processing of converting multivalued image data to two-valued image data, the present invention is not restricted to this but is also applicable to image processing converting M-valued image data to N ($M > N$)-valued image data on the basis of error diffusion. In order to reduce the bit number, simple binarization or error diffusion may be employed in place of the multivalued dithering.

Although the present invention has been described and illustrated in detail, it is clearly understood that the same is by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of the present invention being limited only by the terms of the appended claims.